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Dinos

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DINOS

A1

Dinos basileuei, ton Di' exelēlakōs cries Strepsiades (A. CL. 828)
He is referring back to an earlier exchange with Socrates. They are discussing rain, which Strepsiades attributes to Zeus pissing into a sieve, and thunder, and Socrates shows both to be due to the clouds

SOC: When they are filled with a lot of water, and carried along by necessity,
being suspended full of rain through necessity, then heavily
they fall against one another, crack and thunder.
STR: But who is the being who lays the necessity of movement on them? Zeus surely?
SOC: By no means. It is a dinos of aether. STR: Dinos? I never knew that:
that Zeus doesn't exist, and Dinos is now on the throne in his place (ib. 376).

There is presumably a pun on ho deina ("so-and-so"). The scholiast tells that the philosophical joke is further complicated by a use of dinos to denote a rounded pot, and this is the point of Strepsiades's subsequent self-castigation for thinking a piece of earthenware a god (ib. 1473). This in itself is not unimportant for our understanding of dinos, for the use of the demonstrative adjective shows that Strepsiades is pointing, and the scholiasts draw the legitimate deduction that an earthenware pot has replaced the familiar statue of Hermes at the entry to the phrontisterion, symbolizing the elimination of the gods in favor of natural forces. Athenaeus (11,467d) has a section on the cup, which he spells deinos. Curiously, there is no reference to Aristophanes. The passages he quotes from other comic dramatists add little: we learn that a deinos holds nine or ten gallons, and someone's forehead is said to resemble an inverted deinos. Aristophanes uses the word again in The Wasps where he recalls the philosophical joke (as editors have sometimes failed to see).

Even if you don't pour wine in for me to drink, I'm carrying this onos
full of wine; I tilt it and pour it in, and the onos opens his mouth
and brays loudly at your dinos, and farts like a soldier.
Don't I exercise a fine authority, as fine as Zeus's,
when I have said about me the very things that Zeus does? (616)

The onos is presumably a two-handled cup, and the poet puns on this. He also puns on dinos. To Philocleon Zeus causes thunder by farting, and he scorns dinos as an explanation.

A2

Before we go further it will be well to adduce the evidence of Euripides. In Alcestis 244 he has the phrase ouraniai dinai nephelas dromaiou. It is possible that this is just an unusually vivid poetical phrase, but Euripides was notoriously philosophy-orientated, as Nestle amply demonstrated in his Untersuchungen über die philosophischen Quellen d. Euripides and it looks very much as if this is a technical term referring to the vortex of the upper air whirling the cloud-drift round. In one of the fragments (593N²) we have aitheriōi rhombōi. In another well-known passage from The Women of Troy (884) Hecabe utters a novel invocation:

Thou support of earth, enthroned upon the earth,
whoever Thou art, Zeus, hard to discern,
physical law or human intellect.....

There is here no mention of dinos or dine, but, as we shall se,, there may be allusion, for the contrast between ananke and nous is related to this concept of physical movement.

A3

The passage from Alcestis makes it highly probable that the philosophical use of dinos or dinē is related to movement. Dinos is applied to round objects, such as the cup mentioned above, or a circular threshing-floor, and the rounded pot which is used as the visible symbol of Dinos might suggest a static concept. But though the discovery of a working astronomical model with epicyclic gearing in an ancient shipwreck has led us to place more credence upon Archimedes's working-models, and even to wonder whether after / a mobile image in the cup of water which does not spill as you whirl it round, we should not be surprised to find a static model of a dynamic event. The basic meaning of dinos or dinē seems to be a whirlpool or eddy in water, and it is this analogy which is applied somehow, somewhere, to movement within the universe. But how? and where?

/ a ll Plato may have had something such in mind in the Republic myth, and though Empedocles uses

A4

I follow the example of Norman O. Brown in offering after each section the principal sources I have drawn upon, as an alternative to laborious and distracting footnotes. The references are not of course exhaustive: they include all views referred to, and any others I have found especially useful. The following books have been contantly consulted:

Burnet, J.	Early Greek Philosophy		London	1920[3]
Diels, H. and Kranz, W. (cited as DK)	Die Fragment der Vorsokratiker		Berlin	1954[7]
Gomperz, T.	Greek Thinkers Vol. 1 E.T.		London	1901
Guthrie, W.K.C.	A History of Greek Philosophy	Vols 1-2	Cambridge	1962-5
Heath, T.L.	Aristarchus of Samos		Oxford	1913
Kirk, G.S. and Raven, J.E.	The Presocratic Philosophers		Cambridge	1957
Skemp, J.B.	The Theory of Motion in Plato's Later Dialogues		Cambridge	1942
Tannery, P.	Pour l'histoire de la science hellene		Paris	1930[2]

B1

Ek Dios archōmestha. To trace the story we shall have to move backwards in time, starting with Aristotle. In De Caelo 1,2 he is arguing to a fifth element. He assumes that natural bodies have a principle of motion within them. All locomotion is either straight or circular or a combination of the two. The four elements of earth, air, fire and water naturally move in a straight line in a vertical plane; if there were no fifth element, circular motion would have no natural place in the cosmos. But circular motion must be primary (a) the circle is complete and finite, the straight line infinite and incomplete (269 a 20) (b) circular motion is continuous and eternal (sunechē kai aidion 269 b 8). The case is argued at greater length in Physics 8. He has already defined nature as "the principle and cause of motion and rest to those things and those things only in which she inheres primarily as distinct from incidentally" (2,192 b 20). In Physics 8,9 he argues the primacy of circular motion (a) because a circle is finite and a straight line is not (b) because complete motion in a straight line, returning to its starting-point requires two movements, up and down again (c) because circular motion is eternal (d) because in circular motion there is no beginning, middle and end definable (e) because the determinative point of a circle is the center, and when a sphere rotates it is in one sense in motion, but in another, through its determinative point, at rest (f) uniform rotation with its unit of the completed circuit is the standard of all measurement of time and motion, being the easiest to calculate (if 4,223 b 18) (g) circular motion is the only uniform motion; motion in a straight line changes velocity, accelerating as it removes itself from the place of rest. From the primacy of circular motion among forms of locomotion, he passes to the primacy of locomotion among other forms of kinēsis, adducing Empedocles, Anaxagoras, the theorists, the Milesians (whom Aristotle treats as a group cf 1,187 a 12) and the Platonists. The passage is important: it makes it unlikely that kinesis in Anaximander and Anaximenes is other than locomotion.

In De Caelo 2,13 he starts from various theories of the mobility or immobility of the earth. He goes on to show that motion must be discussed not in relation to a single element but in relation to the total cosmos. Is motion natural phusei or enforced biāi? There cannot be enforced motion unless motion exists in nature; the same is true of rest. It follows that if the earth is at rest biāi the enforced rest must arise from some natural rest or motion. This will be the vortex (tēn dinēsin). Aristotle is assuming his proof of the primacy of circular motion, but he is also speaking historically, for he goes on "This is the cause that all allege, reasoning from what happens in liquids and in the air; for in these the larger and heavier objects are always carried towards the middle of the whirl (dinē)" (295 a 11) (Guthrie must be wrong in "This is the name which all agree is giving...." since the name does not seem to have been used by the Milesians, if they held such a theory, or Anaxagoras, who certainly did). The earth remains at the center of the vortex, either by reason of its flatness and size or on the Empedoclean motion of the cup of water swung swiftly round (which we shall discuss later). Aristotle subjects these views to some criticism (a) the absence of an account of the earth's natural motion (b) the mobility of the Earth in the rule of Strife in Empedocles, not to be explained by the vortex at that point (c) "Even if in the past it is through the vortex that the parts of the earth were carried to the center, through what cause is everything that has weight still carried towards it? Surely the vortex is not drawing close to us" (295 a 33) (This is precisely what Anaxagoras seems to have said) (d) Why does fire move upwards? Not through the vortex! If fire has a natural motion, so may earth.

(e) Heaviness and lightness are not defined by the vortex; they must have existed before the vortex. Aristotle does not follow out this criticism, but he means a doctrine of natural positions which does away with the need for a vortex.

There is one other important relevant passage in Aristotle. This is De Anima 1,3, Aristotle is discussing the kinēsis of the soul, and isolates four forms of kinēsis, locomotion, change of state, decay and growth. The discussion which follows is not very clear, but Aristotle rejects movement in a straight line for the soul on a priori grounds; if its natural movement were up it would be fire, if down it would be earth. He also rejects the circular movement which Plato postulated in Timaeus. noēsis is not periphora, nor will circular movement do as a model for thought, since it is the essence of thought to move to a conclusion. Plato had linked the motion of the soul with the motion of the heavenly bodies. Aristotle comments that the reason why the heavenly bodies move in a circle is obscure (407 b 6), but there is nothing in the essential nature of the soul to link it will circular movement, nor any profession that circular movement is better.

Aristotle is important as a source for earlier views on the vortex and for his criticisms of them; he is also important because while rejecting the model of the whirlpool or whirlwind in favor of his own theories of natural position and natural movement, he offers interesting theoretical justifications of the primacy of circular motion. Some of the analysis is no doubt original with him, but is is unlikely that none of the arguments had occurred to earlier thinkers.

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Guthrie, W.K.C. Aristotle: On the Heavens London 1939

Wicksteed, P. and Cornford F.M. Aristotle: The Physics 2 Vols London 1934

B2

Plato need not long delay us: the problems are fascinating, but of limited relevance to the present enquiry. In Laws 10 (893 b 1) he isolates ten kinds of motion (i) circular motion round a fixed center (ii) locomotion in a straight line by gliding or rolling (iii) combination (iv) separation (v) measure (vi) decrease (vii) coming into being (viii) destruction (ix) the capacity to move another object and be moved by another (x) the capacity for self-movement and moving other objects. Of these the last is supreme. But a little later (898 a 2) he asserts that uniform circular motion, as of a spinning globe, is the best model for the revolution of reason, and argues from this to a link between the circular movement of the sky and a guiding intelligence. The argument picks up Timaeus. There the Divine Artificer constructs the cosmos as a single unit (33 c ff), a living creation, in the most appropiate shape, namely a sphere, and assigns to it the form of motion appropriate to reason and intelligence, namely revolution round a fixed point. This motion is a rotation of the whole universe with all its contents. The rectilinear motions which disturb the simple picture of rotation, up, down, backwards, forwards, left, right, are irrational and intrusive. Somewhat later (46 f ff) Plato picks out a contrast between nous and anankē, linking nous with aitia and anankē with synaitia; anankē here refers to physical causes which serve to rational end. In The Laws he links anankē with tychē in the explicit phrase kata tychēn ex anankēs (10,889 c). Nous is associated with uniform circular motion, anankē with random movement. It follows that Plato rejects the idea of an irrational vortex, since that would for him be a contradiction in terms; we may make a reasonable deduction that this passage is directed against the atomists. It is interesting that later Plato uses the model of the winnowing-fan (52 e ff).

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In Democritus the doctrine of the vortex is explicit and familiar. The elements are stated to be perpetually moving in the void aei kinoumenōn tōn ontōn en tōi kenōi (D.K 68 A 40). This motion is random, like the motes in a sunbeam (cf Arist. An. 1,403 b 31). Here, clearly, perpetual movement is not identified with movement in a circle, but this may be original with the atomists. Aetius states that Democritus regarded vibration as the basic motion (68 a 47) palmos. He may be reading Epicurean thought back into the earlier atomists; yet we are still dealing with thought based on analogy, and the image of winnowing is of some importance. Then for some reason not stated, a whirl or vortex was separated off from the whole, of all kinds of shapes (68 A 67; B 167). Simplicius attributes this to chance (cf Arist. Phys. 2 196 a 24); and some modern interpreters have identified this with statistical probability; Democritus would not have so put it, but it may not be too far from his intent. In the vortex there is the repulsion of unlike atoms (68A37) and the attraction and entanglement of like to like. An important fragment explains this first in terms of the familiar "Birds of a feather flock together" and then of the tendency of seeds in a sieve to come together in their kinds Kata ton tou koskinou dinon or pebbles under the action of waves (68 B 164). The most important aspect of this for our concern is panta te kat' anankēn ginesthai, tēs dinēs aitias ousēs tēs geneseōs pantōn, hēn ananken legei, everything happens according to necessity, the vortex being responsible for the coming-unto-being of all things, and he calls this necessity (D.L. 9,45) "This" can grammatically refer to vortex or coming-into-being, but it is clearly the former; compare the phrase kat' anankēn men kai hypo dinēs (68 A 83), or Aetius's definition of anankē in Democritus as the resistance, locomotion and impact of matter (68 A 66). Necessity then means physical or natural law, and that is identified with the vortex which initiates the process. The concept is important for our understanding of the Euripides passage in The Trojan Women: the vortex may be there in the thought of physical law or necessity. One additional point: the dinē continues: at least it is reasonable to see it in Lucretius's caelo turbine (5,624 cf. 510) where it is associated with the view that the close stars move more slowly than those more distant: it is thus present as well as primal, astronomical as well as cosmogonical. Some have thought, on the basis of a passage in Epicurus's Letter to Pythocles (92) that Democritus held a whirl within a stationary rim. I can see nothing in this mutilated and obscure passage which applies to Democritus, and Lucretius did not so understand him. Democritus is not in question in Aristophanes or Euripides: I have shown that his major contribution to atomic theory is to be dated to 405 B.C. He stands at a later point in the succession.

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Schreckrenberg, H. Ananke Munchen 1964

B4

Behind Democritus stands the obscure figure of Leucippus. According to some versions he came from Melos (D.L. 9,30). This is interesting, for Socrates is jocularly called "the Melian" in The Clouds (798). The reference is probably to Diagoras and his "atheism", but is is just possible that Leucippus is in question; it is however more likely that Leucippus also receives the attribution as a mark of atheism in some lost comedy which has been taken as serious evidence. Leucippus is exceedingly difficult to date. Diogenes of Apollonia antedates The Clouds with some of his writings, and Theophrastus claimed that he took some of his eclectic views from Leucippus (DK 64 A5). This need not be true, or if it were it is possible that he modified his thinking in the light of Leucippus at a later point. There is no evidence of atomism in Aristophanes or Euripides or Plato's Phaedo, and it seems likely that Leucippus wrote The Great World-System in the last thirty years of the fifth century. The picture we have of his thought at this point is not essentially different from that of Democritus. The only surviving sentence of Leucippus is "Nothing comesinto being at random; everything in accordance with a principle and by necessity" (67 B2). This accords with the use of necessity in Democritus, which is identified with the vortex. The words do not mean, as they are often translated, "Nothing happens", Leucippus would not have written chrēma for that (cf ouden chrēma gineta' in Anaxagoras 59 B 17, from which the phrase is borrowed) they are thus not incompatible with an originally random movement, but until the vortex is produced, no thing comes into being. We have two other words which must come from Leucippus; he spoke of chitōna kai hymena, a covering or membrane which formed in a circle round the universe (67 A 23): the circle is important. In Aetius's summary of The Great World-System again we find the indivisible bodies in continual motion, which is explicilty said to be apronoēton kai tychaian. In the summary in Diogenes Laertius there are some important passages (which Kirk, whose treatment of the atomists is curiously perfunctory, does not excerpt) tēn gēn ocheisthai peri to meson dinoumenēn; the earth (which is in the shape of a tambourine) is supported as it rotates around the center (D.L. 9,30). He proceeds to speak of the production of a vortex in which like came to like, the fine atoms passed outwards, as if they had been sieved out; the rest remained and became entangled, forming a spherical structure (the membrane above), which enclosed all kinds of bodies. "As these were whirled round in accordance with the resistance of the center (Kata tēn tou mesou antereisin), the surrounding membrane became thin, as the continous bodies unceaingly flowed together in accordance with their contact with the vortex. In this way the earth came into being, as the things which had been carried towards the center remained together there" (D.L. 9,32). Thus we see in Leucippus no explanation of the origin of the vortex. Since the vortex was set up there is a tendency of like to come together with like; this is taken from Anaxagoras, but for Leucippus likeness is of shape and size not sort and substance, and it is this that sieves out the fine atoms and leaves others forming a spherical membrane. What happens then has been well explained by Burnet; it puzzled Gomperz. Gomperz wrote (1,339 E.T.); "these effects were the precise contrary of what they should have been by the laws of physics! The centrifugal force which is released by a rotatory movement is doubtless admirably adapted to sift an agglomerated mass of matter. But, as every centrifugal machine would show, it is the heaviest substances which are hurled to the greatest distance." Gomperz's constructive explanation merits reconsideration. The motion of a whirlwind or "twister" or even of slighter eddies will carry off lighter objects but leave heavier, and because of the friction as it approaches the ground does in fact deposit matter at its center. Gomperz suggests a false extrapolation from observed phenomena. It is even more likely that Leucippus had in mind the tendency of a maelstrom to suck boats to its center. What Burnet has shown is that Leucippus offered a physical explanation of this in terms of the contact between all parts of the vortex, so that the motion of the outer membrance is communicated (and, we may add, in a closed system) to all inside. The speed of revolution is of course slower towards the center, and this is what Leucippus means by the resistance of the center. We now understand more clearly the residual rotation of the earth, and its equilibrium in the center, there being no "up" and "down" in the void for the early atomists, as there was for Epicurus, and the rotation of the vortex being horizontal in relation to the earth: the word ocheisthai is interesting in relation to Euripides, though Leucippus is not likely to be his source.

As for B 3

B5

The views of Diogenes of Apollonia are plainly in question in The Clouds, as the use of ikmas would tell us, even if nothing else did (DK 64 A18) cf A. Clouds 233). He reaffirmed a monism based on air, against the pluralism of Empedocles and Anaxagoras, and accepted from Anaxagoras the doctrine of a divine intelligence which he identified with air. In general the formation of the world was due to the rarefaction and condensation of air. He stated that everything is in motion, though we have no evidence of his speaking of unceasing motion. Kirk took the view that this motion was rotatory, but he depended in part for his view on an emendation by Kranz. The MS reading makes sense: "where the dense ran together it made a solid mass" (systrophēn poiesai; Kranz systrophēi gēn poiēsai, which Kirk renders "centripetally" Rotation is, however, to be seen in the heavenly bodies (64 A 12). The words dinos and dinē do not appear in our sources, so that it is dangerous to be dogmatic: with his debt to Anaxagoras, Diogenes may have derived his image of the rotation from him rather than from Empedocles or Leucippus. Equally, our sources are scanty, and Diogenes was eclectic: he cannot be ruled out as Aristophanes's source.

B6

Anaxagoras is more important. After his general account of Nous he proceeds: "Mind controlled the whole revolution, so as to revolve from the beginning. It began to revolve first from a small beginning, and now revolves to a greater extent, and will revolve to a greater extent in the future. Mind knows all the things which were mingled together, separated out or divided off. Mind organized all that was going to exist, all that existed in the past but does not exist now, and all that exists now or will exist in the future, including this revolution, the present revolution of stars, sun, moon, air and fire (all in process of being separated off). This revolution produced the process of separating off: the dense is separated off from the rare, the hot from the cold, the bright from the dark, and the dry from the moist "(DK 59 B 12)." To this we may add two more passages: When Mind initiated motion, there was a process of separating off from the totality in motion, and all that Mind set in motion was divided out. As things were set in motion and divided out, the revolution greatly increased the process of division "(59 B 13)".... as these things revolved in this way and were separated out by the force and speed. Speed produces force "(59 B 9). The interpretation of this has occasioned less controversy than other parts of Anaxagoras, but it is extremely difficult to interpret and even to translate. In the first quotation egno is most easily rendered "knows", and Simplicius so understood it (Cael. 608,27ff.), but Lammli argued forcefully for the meaning "determined". Aether is clearly "fire",as Aristotle understood (Cael.270 b 24; 302 b 4; Meteor 364 b I4). The MSS in the next sentence have haute, but some editors prefer to emend aute, "the actual revolution". In the next quotation it is not clear whether apekrineto is impersonal, as I have taken it, or whether Mind is separated off (so Heidel, Diels-Kranz, Guthrie). I take apo tou kinoumenou pantos to mean not "all that was moved", wh ich could be unambiguously expressed by a different word order, but "the all in motion". This might be contradicted if apo tou mikrou and epi pleon in 59 B I2 refer to the areas affected, but they seem to me vaguer than that. In any case once the outer part of the universe is in motion it is easy to speak of "the universe in motion". We may reasonably postulate increasing acceleration. The word for revolution is not dinos or dine , which nowhere appears, but perichoresis : the verb appears of Thales journeying round Greece (D.L.I,44), of kingship coming round in succession (Hdt.I,2I0), or of a waiter going round with the water (A. Birds 958) : it is noncommittal and suggests no clear image. Anaxagoras may have believed (so Cleve) that lifeless bodies of themselves move only along a vertical axis. Any other motion requires an explanation. Nous therefore, so to say, put itself into orbit, and that revolution has gradually been transmitted to the whole universe, and the universe has changed in accordance with centrifugal force. This is why Anaxagoras does not use dine (which was available to him from Empedocles); his model is different;the appearance of dinos in a vague passage from Clement is hardly to be pressed to the contrary (59 A 57). Hence the flinging out of stones to form sun, moon and stars (59 B I6; A 42; A 7I and especially A I2). Anaxagoras's view however is not a simple one. He evidently thought that Nous imparted its revolution first at the outer edges of the universe, and tended to pick up the lighter bodies, leaving the heavier towards the centre (59 A 42)cf. D.L. 2,8).Then

comes a second stage when the centre is in motion and tending to fling its heavier parts outwards, though Anaxagoras thought of them being sucked out. This must be emphasized. Anaxagoras understood the results of centrifugal force, but not the cause, hence Guthrie is clearly right against Burnet and Cleve in claiming that the earth is not itself revolving, though he is wrong in applying the model of the vortex or eddy. In addition Anaxagoras had in mind a model derived from Empedocles, of a cup of water whirled round without losing the water, and seems to have thought that really violent revolution holds the objects in its sweep tight, so that they do not fly outwards or fall inwards (59 A 12). Guthrie seems to me wrong in his interpretation of the increasing revolution : "The notion that the rotating cosmos was at first small, and is continually growing by drawing in more of the infinite surrounding it, is interesting, particularly in the light of some recent cosmogonical theory" (2, 296). I can see nothing of this at all. The revolution started at the outside of the cosmos, and the increase refers to the spread of the revolution from the periphery towards the centre, which it has not yet reached.One final point in Anaxagoras. He speaks of the air as supporting the earth (pherein epochoumenen ten gen 59 A 42); but he also speaks of air above (ton anothen aeros). This is clearly the origin of Euripides's o ges ochema kapi ges echon hedran , and we need not look further. One last point. The famous Socratic criticism that Anaxagoras made no practical use of Nous in arranging the details of his cosmos (Plat. Phaed. 98 b 7) shows that Anaxagoras forms the bridge between the identification of physical law (ananke) with Love and Strife in Empedocles and with the vortex in the atomists.

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B 7

So far as we can see it was Empedocles who coined the concept of the dine. The word comes in two of the fragments. One from Purifications (D K 33 B 115) tells of the tossing of the sinful soul from air to sea, sea to land, land to the sun's rays, and from the sun to"the eddies of air" (aitheros embale dines). This need not be a technical term; but it certainly looks like the proximate source of the passage from Alcestis. The other is more important (33 B 35)

> when Strife has reached the lowest depth
> of the vortex, and Love is at the centre of the rotation,
> by her power all these things come together to be one single thing

As far as we can see Empedocles describes the formation of the world out of a homogeneous unity under the influende of Strife. The original change is one of separation; air is separated off, surrounds the world, and solidifies to enclose it; fire follows, so that two hemispheres are formed, one of fire and one of fire and air. These begin to revolve because of the preponderance of fire in one region (31 A 30). Further the construction of the earth by the force of the rotation (tei rhymei tes periphoras) squeezed water out (31 A 49). Aristotle adds that Empedocles used the model of a cup whirled round without the water spilling to explain the immobility of the earth (De Caelo 2, 295a 13); and again that "the earth remains at the centre because of the vortex" (300 b 3). All this is difficult of interpretation. That an imbalance of the elements first separated off might produce motion is reasonable, but there seems no reason why it should produce rotatory motion; probably we must say that Empedocles adduces his explanation of the origin of motion, and accepts the observed fact of rotatory motion, but failed to bring the two fully together. We may accept the accumulation of the heavier bodies at the centre, and their constriction, in terms of the whirlpool or whirlwind. But the cup in motion not at the centre seems a curious model to explain the immobility of the earth at

the centre. Some interpreters allege misunderstanding by Aristotle, Mugler of the model, which he suggests was a solid body floating in liquid in a cup, Cherniss of the thing to be explained, which he suggests was why the water, air and fire outside do not fall on the earth. Either of these is ingenious; both make Aristotle ingenuous. Gomperz may be right in suggesting that Empedocles had a keen scent for analogies which he applied over-hastily : "Set the goblets revolving quickly, and their contents will not escape; set the firmament revolving quickly, and the earth at its centre will not slip." (I, 242) Aristotle (De Cael. 295 a 31) says that the earth cannot be held at the centre by the vortex because it is impossible to adduce the vortex once the elements are separated. I do not see this. Once the initial separation has been produced by Strife, and the vortex set in motion Empedocles plainly thinks that the vortex will continue the process of separation with the heavy bodies tending to the centre and the light to the periphery; when the separation is complete, the vortex will maintain the same conditions. Then in fr. 35, which represents the advance of Love, Love ousts Strife from the centre of the vortex; we must with Diels-Kranz, Raven and Guthrie insert fr. 36 in place of the doublet 35,7. The result, as O'Brien says, must be that as Love's power increases and the elements begin to commingle again the heavy things have to move outwards, contrary to the action of the vortex, and this paradox accounts for the precise mention of the vortex here. One final point about Empedocles. He evidently did not contrast the action of Love and Strife with the action of the vortex, and identify the vortex with necessity, but made necessity identical with his motive powers Love and Strife (31 A 45). This shows that the identification of the vortex with necessity was original with the atomists.

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B 8

It is however necessary to look behind Empedocles. On the one hand there is the tradition of Pythagoras and Eleatics, on the other Ionian physical speculation. Most of us move uneasily in the world of the early Pythagoreans. There are two points to single out. The first relates to the celebrated columns of opposites. There, rest and straight are in the good column, motion and curved in the evil. Such an analysis stands squarely in the path of the perfection of circular motion, and almost justifies Burnet's over-schematic and over-dogmatic statement that Pythagoras broke with the vortex-theory. The Pythagoreans were in fact fascinated by figures formed of straight lines, equating for example the pyramid with fire, the cube with earth, the octahedron with air, and the icosahedron with water, and these are of course important factors in the cosmogony in which the world is generated out of numbers, the point 1 flowing into the line 2 which flows into the plane 3 and that into the solid 4. This is a very different world-picture from any we have examined so far; as evidence it is negative but not valueless. But, secondly, the Pythagoreans did hold to a spherical universe, and in Alexander Polyhistor's analysis, which Raven has carefully examined, the cosmos is formed from fire, water, earth and air: "and from these comes into being a cosmos, endowed with life, intelligent, spherical in shape, encircling the earth in the centre, (itself spherical in shape and inhabited round about)" (D.L. 8,25). So that among the Pythagoreans, despite the columns of opposites there was some idealization of circularity, though not of circular motion. It is just here that Parmenides is important. It has been argued that Parmenides was exploring the logical consequences of accepting the first column and rejecting the second. The result is, interestingly, the acceptance of sphericity, and of a ball as the model for the universe.

for the universe (eukyklou sphaires enalinkion onkoi surely means "like the mass of a well-rounded ball" not "like the mass of a well-rounded sphere" and is not to be taken as a verbal attempt to escape spatial extension : D K 28 B 8, 43), but the rejection of motion.

Alcmaeon is in all this the most important figure. He apparently used the analogy of circular motion and psychic function; indeed he probably devised it, and it was from him that it passed to Plato (Tim. 40a; Laws 10, 895 a). According to Aristotle (D K 24 A 12) he stated that all divine things are for ever in continuous motion (kineisthai gar kai ta theia panta synechos aei), moon, sun, stars, and the whole sky, and he used this as the model to show the immortality of the human soul. Another passage from Aristotle quotes Alcmaeon as saying that men die because they cannot join the beginning to the end (24 B 2). Michael Apostolius, who also cites the passage, adds kyklos gar an en (Corp. paroem. 2, 674). We are not here concerned with the human soul. The continuous motion, however, must be kyklophoria, and (though we cannot be certain about relative dates) it looks as if Empedocles devised the model of the dine, but theories of circular motion in the cosmos antedate him, and we may infer a possibility that earlier theories of continuous or unceasing motion do refer to motion in a circle.

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Cornford, F.M. "Mysticism and Science in the Pythagorean Tradition" C.Q. 16 (1922) 137-50; 17 (1923) 1-12

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Heidel, W.A. "Qualitative Change in Presocratic Philosophy" Arch. Gesch. Phil. 14 N.F.7 (1906) 333-79

Raven, J.E. Pythagoreans and Eleatics Cambridge 1948

B 9

Anaximenes has always been a shadowy figure alongside the other pre-Platonics. Here there is no indication of a primal vortex in our sources, apart from a general statement by Aristotle in talking of the vortex that all who generate the sky claim that the earth comes together at the centre (De Caelo 2, 295 a 7); as Kirk says, the statement would have been enough to make Theophrastus explicit, had there been anything to be explicit about. The cause of change in Anaximenes is the rarefaction and condensation of the primal air (D K 13 A 5). But Theophrastus does attribute to Anaximenes a doctrine of eternal motion. In pseudo-Plutarch the statement appears immediately after the doctrine of rarefaction and condensation : "the movement" i.e. the process of change "exists from eternity" (13 A 6). In Hippolytus the statement is expounded : "it" sc. air "is always in motion; for it would not be producing all the changes it does if it were not in motion" (13 A 7). (Kirk treats this as a generalization : "things that change do not change unless there be movement") (It is not clear whether metaballein is transitive or intransitive : I have essayed an equally ambiguous translation) Heidel equates this eternal movement with the vortex, on the basis of a further passage from Hippolytus which suggests that the heavenly bodies move round the earth with a circular motion, like a turban round a head; the image must come from Anaximenes, but it is not clear whether he was referring to the wrapping of the turban in the first place, or the twirling of the completed turban; probably the former. He regarded the heavenly bodies as leaves floating on the air; the only passage to tell against this - helon diken katapepegenai ta astra en krystalloeidei/ cannot mean "fixed like nails in the substance /(13A14 like ice" which would be an odd thing to do, and does not accord with the other evidence; we must accept Guthrie's physiological explanation of a spot on the viscous membrane. The image of leaves on air (13 A 7; 14; 15) does suggest that the air is in motion carrying the leaves; and Aetius suggests that the stars bend their courses when opposed by condensed air (13 A 15). The general motion is certainly circular (sympericheromena 13 A 14). It follows that in Anaximenes (a) the image of the vortex or whirlpool was not explicitly found (b) there is a circular movement of the air round the earth (c) we are not justified on the evidence before us in equating this with the eternal process of condensation and rarefaction and postulating a primal cosmopoietical vortex. One final point about Anaximenes : the use of ochoumenen or epocheisthai of the earth's relation

to air suggests that he is the ultimate source of Euripides's phrase in The Women of Troy; the proximate is Anaxagoras.

Guthrie, W.K.C. "Anaximenes and to krystalloeides " C.Q. N.S. 6 (1956) 40-4

Heidel, W.A. "The DINE in Anaximenes and Anaximander" C.P. I (1906) 279-82

B 10

So to Anaximander. Here we face the same problem as in Anaximenes. There is no doubt that the heavenly bodies are regarded as cartwheels encircling the earth (D K 12 A 21; 22), tubes full of fire which appears through an aperture. Nothing else is completely clear; there is in fact curiously little reference to motion in our sources, though the word peripheretai does appear once (12 A 21). Probably, however, the image of the wheel is meant to suggest that the whole tube is rotating. There is an important sentence in Aetius which neither Kirk nor Guthrie discusses, and Diels-Kranz classify under Anaximenes (13 A 12) hoi de trochou diken peridineisthai. This must refer to Anaximander. The appearance of a word in our doxographic sources is of no final moment; still it is sufficient indication that the dine may be astronomical as well as cosmogonical. As to the cosmogony, the opposites are separated off through the eternal motion, apokrinomenon ton enantion dia tes aidiou kineseos (12 A 9). Each unit within the phrase is controversial; so is the whole phrase. I agree with Kirk against Holscher that we can rely on this as authentically based on Theophrastus, in the light of pseudo-Plutarch (12 A 10). Aristotle has ekkrinesthai (Phys. I, 187 a 20); Theophrastus is likely to represent Anaximander's intention more accurately; the separation is off not out. But what is the eternal motion, which is also mentioned by Hippolytus (12 A 11) ? Here we are confronted with two main schools of thought. One is vitalist, the other mechanistic. One stresses a general statement by Aristotle (Phys. 8, 250 b 11), which identifies a motion which exists deathlessly and unceasingly with a kind of life, and emphasizes the divinity of the Indefinite as inevitably involving the power of movement;it also draws attention to biological analogies in Anaximander's cosmogony. The other stresses the obvious physical facts : eternal motion is circular; circular motion does produce centrifugal force and the tendency to "separate off"; it is true that Theophrastus does not speak of dine in connection with Anaximander, but that may be merely that he did not find the actual metaphor, which Empedocles seems to have coined. It is not correct to identify all circular motion with a vortex or whirlpool, which is a particular model. I incline to believe that circular motion must be intended, but that it was not developed into a vortex-theory for another century.

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Kahn, C.H. Anaximander and the Origins of Greek Cosmogony New York 1960

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Seligman, P. The Apeiron of Anaximander London 1962

Tannery, P. Pour l'histoire de la science hellene Paris 1930(2nd.ed.)

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B II

Can we go back further ? Not with any certainty. The Orphic - or non-Orphic - primal egg is hardly to the point, even if it can legitimately be placed in the earlier period of Orphism; in any event it is curiously infrequent in the Near East though common in other parts of the world. But eggs do not rotate. More important is Oceanus. Oceanus in primitive Greek thought is a river which encircles the world. It flows of course, so that there is circular movement round the earth; the epithet apsorrhoos means "flowing back into itself". The myth of Oceanus is in the background of Thales, and it is possible that it suggested the model of the whirlpool. It is curious that, so far as I can see, in the surviving creation-epics and hymns of the Near East there is no mention of the rotation of the sky or the whole cosmos as part of the process of creation, not even in Mesopotamia with their astronomical preoccupations, either in Enuma Elish or in the more fragmentary accounts or in Berossus. The cosmological vortex is a Greek concept.

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Heidel, A.	The Babylonian Genesis		Chicago I95I (2nd. ed.)
Linforth, I.M.	The Arts of Orpheus		Berkeley I94I
Nilsson, M.P.	Geschichte der griechischen Religion	vol.I	Munchen I955 (2nd. ed.)

C I

A little science, which is curiously difficult to track down, as vortex-theory is frequently omitted from general handbooks of physics, and related to specific problems in textbooks of hydrodynamics and aerodynamics; further, when articles appear, they tend to be highly technical. The great investigator of vortex-theory was the German Helmholtz, who wrote comprehensively on the subject, but the importance of aerodynamics in the twentieth century has led to new discoveries.

The concept popularly called centrifugal force (it is not really centrifugal) is relatively easy for the layman to understand. A point on the surface of a spinning wheel has at any given moment an angular momentum tangential to the wheel, and if it is not held to the centre by the forces inherent in a rigid structure it is in that direction that it will tend to move. The phenomenon is familiar observationally. Place a pebble on a potter's wheel, rotate the wheel, and the pebble will be flung off. This is the model which Anaxagoras is using.

The vortex is more complex. Hydrodynamics uses the concepts of irrotation (flow in a given direction without any rotational element) and vorticity. Vorticity arises in water or air from the meeting of two currents. In a stream with smooth, regular bottom and sides the flow is irrotational, but irregularity will set up cross-currents and a tendency to vorticity. A vortex can most easily be considered in a closed system, say the stirring of a glass of water: the fact that in whirlpools and whirlwinds the container is more water and more air does not affect the principle involved. Here two phenomena may be noticed. The first is that where the velocity is highest the pressure is lowest: hence the fact that the water at the centre is lower than at the rim. The principle may be shown experimentally by forcing water through a pipe of irregular diameter and inserting tubes into the pipe at right angles to the direction of flow. Where the pipe is narrower and the velocity of flow consequently greater the water will rise less high in the tube than where the pipe is wider and the velocity smaller. Bernouilli identified the formula $p + kv^2 =$ constant, where p is the pressure, v the velocity and k is constant. The other phenomenon is that of boundary-layer flow. This is a flow in a vertical plane from the surface-centre to the outside, down the outside, along the base to the centre and up. It is this that in a whirlwind tends to draw loose objects on the surface of the earth to the centre, from which it may lift them, unless the pull of gravity is too strong, in which event there is a tendency for them to accumulate at the centre.

There is a further point. We are sufficiently familiar through Jules Verne with the concept of the maelstrom which sucks boats down and into the centre. The picture was familiar to the Greeks through Charybdis in The Odyssey, though there there is a reverse process of regurgitation after three days. The effect of the boundary-layer flow and the centrifugal tendency is for the denser bodies to move towards the circumference and the

lighter bodies towards the centre. As a boat is lighter than water (or it would sink) there is a natural tendency for boats to move towards the centre of a whirlpool. It is possible that this is accentuated by gravity, since by Bernouilli's Principle the centre is lower than the circumference and the pressure at the centre less. It is likely, however, that ancient belief about whirlpools would not discriminate between a vortex in a channel, and a vortex in a container like a bath, when the plug blocking the outflow is removed. Plainly in this last there is an additional force of suction drawing objects within the bath down and towards the point of outflow. It is even possible that in some maelstrom effects there is a drainaway of some kind creating a suction. At any rate the Greeks would observe the movement of solid bodies along the surface of the earth to accumulate at the centre during a whirlwind or eddy of air, and they were familiar with the maelstrom effect which is in fact the obverse of the same coin. These are the models used by those who postulate a vortex or eddy.

Private communications from Prof. Murray Braden, Prof. Charles Coulson, Mrs. Elnora Ferguson, and Mr. John Holding.

C 2

Some general conclusions :

(a) Speculation on a circular movement as part of cosmogony is Greek : it is part of the general process of replacing mythology by science and mathematics Dinos did indeed kick Zeus out.

(b) That the primal movement was circular was suggested by observation of the sky and the heavenly bodies: a further factor was the apparently continuous nature of circular motion by contrast with rectilinear which to the Greeks tended to a goal or limit. The theoretical perfection of the circle or sphere plays a small part.

(c) There are various models for circular motion. Anaximander uses a wheel spinning. The model of the whirlpool or whirlwind starts with Empedocles, who scatters his analogies freely, is rejected by Anaxagoras, and taken up again by the Atomists. The different models offer different emphasis and even different implications; it is important to stress that the concept of cosmic rotation does not of itself imply the thought of vortical flow. In general, although I have used it, the mathematical term "vortex" is not a true representation of dinos or dine, which would be better rendered "eddy" (incidentally, in The Clouds a means of maintaining the pun on "so-and-so"). Among the most persistant models involved in cosmogony is the sieve or winnowing-fan. Sometimes this is a model for random movement producing orderly results: at least once the word dinos is explicitly applied to it.

(d) The atomists equate the dine with ananke or natural law. This in turn is equated, at least by the time of Plato and Aristotle, with tyche.

C 3

(a) Euripides was au fait with the philosophical implications of the latest physical speculation. The passage from Alcestis is almost certainly based on Empedocles; that in The Women of Troy, in which the vortex is not explicitly mentioned, on Anaxagoras, and we are probably right to see in him the distinction between nous and ananke.

(b) Aristophanes's source is curiously difficult to pinpoint. The problem is the masculine dinos. This is used only by Leucippus and Democritus, who also use dine; Empedocles uses the feminine, Anaxagoras abjures the analogy, and the word does not appear in our Diogenes sources, nor is it certain that he believed in the idea. But the absence of any trace of atomism in Socrates's autobiography inPhaedo (clearly on all grounds an account of Socrates's development not Plato's) proves that the work of Leucippus, even if in being, was not directly known at Athens in the 420s. The main allusions in The Clouds are to the views of Diogenes. Certainty is not possible, but all in all I am inclined to think that in the absence of any other candidate we should take The Clouds as evidence of a vortex-theory in Diogenes, which he may possibly have taken over from Leucippus. I do not profess to know why anyone should change from the feminine dine to the masculine dinos, but Aristophanes preferred the masculine, whether or not he found it in his proximate source, because it gave him a pun, and because it provided a suitable usurper to oust Zeus.

John Ferguson